

## A DESCRIPTION OF SURFACES CREATED ON THE HYBRID MMC BY THE AWJ CUTTING TECHNOLOGY

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### ABSTRACT

*Metal Matrix Composites (MMCs) are one of the appropriate choice of materials in today's manufacturing industries for various engineering applications. However, machining of such hard materials is still a challenging task due to high tool wear in conventional methods. Non-conventional method such as abrasive water-jet cutting is one of the preferred choice for processing of these materials. In this work, the study of machined surfaces produced by Abrasive Water-Jet (AWJ) cutting on hybrid MMC A359/Al<sub>2</sub>O<sub>3</sub>/B<sub>4</sub>C is discussed. Three different samples of producing hybrid MMC were taken for the study at different proportion (2%, 3% and 4%) of each reinforcement. The study includes the comparison of AWJ created surfaces for each sample in terms of microstructural examination and surface characteristics. It also focused on 2D and 3D detailing of the surfaces to discuss the major points of topographical aspects. The results reveal the successful cutting of hybrid MMCs.*

**KEYWORDS:** Abrasive Water-Jet Cutting, Surface Topography, Surface Texture & Hybrid MMCs

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### INTRODUCTION

In the current scenario, the manufacturing industries continuously demanded the novel materials for specific engineering applications [1]. Such demands leads to the introduction of composites in the field of automotive applications. These materials exhibit the properties like to improve mechanical, thermal and electrical properties compared to other engineering materials [2]. Metal Matrix Composites (MMCs) are preferable choice among the class of composites [3].

In recent years, the MMCs are the better option for replacement of heavier construction materials like steel or cast iron for better performance regarding weight reduction and excellent fuel efficiency [4]. MMCs can be developed by some techniques, which vary considerably according to the type of reinforcement [5]. The selection of the development techniques depends upon the standardized dispersal of the reinforcements into the matrix material [6]. Besides of the excellent qualities of MMC's, the machining of such materials are still a challenging task because of the presence of hard abrasive particles and its high hardness which results in an inferior surface quality and lower stage of machining outcomes [7, 8]. In AWJ technique, the high pressure, high velocity water-jet strikes the workpiece material which leads to the cause of plastic deformation to remove desired materials from the surfaces [9]. The use of AWJM increased in recent years due to its capability to cut or machine hard to cut materials such as ceramics, marbles and composite without any thermal distortion and cutting force. The method is also an application of mining such as cutting of rocks [10]. Various authors have worked on the AWJ cutting of hard materials like steels, MMCs etc. Hamatani and Ramulu [11] worked with Al/SiC and TiB<sub>2</sub>/SiC ceramics to

perform AWJ machining. They discuss the effect of process parameters on machining outcome in slot cutting operation. The AWJ machining of A7475 was conducted by Boud F [12] to examine the surface residual stresses and textures. They observed the improved fatigue life of the sample used by introduction of compressive residual stress. Srivastava et al [7] reviewed the effect of conventional and non conventional machining on various composites. The merits and demerits of machining processes were also discussed. The effect of traverse speed of the nozzle on machined surfaces of hybrid MMC was reported by Srivastava et al [9]. In his work, the detailed study of surface residual stresses, microhardness variation and 3D detailing of machined surfaces were performed. Nag A et al [13] discussed the effect of type of abrasive such as borton garnet and olivine in the processing of hybrid MMC's. Nag A et al [14] also studied the diametral deviation of a cylindrical workpiece of hybrid MMC during processing of AWJ turning. Mardi KB et al [16] worked on magnesium based nano composite and evaluates the water pressure effect during AWJ processing. The optimization of machining outcomes of the AWJ turning the process on hybrid MMC was done by Srivastava et al [17]. Abrasive mass flow rate, rotational speed of cylindrical workpiece and traverse speed of the nozzle was used to evaluate the MRR and surface roughness. Srivastava et al [18] has compared the AWJ and Wire EDM (WEDM) processing of hybrid MMC's to discuss the differences in surface integrity. They discussed the surface morphological and topographical phases of surface characterization to measure up the merits and demerits of AWJ and WEDM processes. On the basis of above literature, it has been concluded that the AWJ processing of composite materials is still a keen area of today's research. In the present work, the objective is to analyse the three different samples of hybrid MMC in terms of surface characteristics and topographical aspects.

## EXPERIMENTAL PROCEDURE

For producing the hybrid composites, A359 aluminium alloy (Si-9%, Fe-0.2%, Mg-0.6%, Cu-0.2%, Ti-0.2%, Mn-0.1%, Zn-0.1%, Al -remaining) is used as a matrix material and two reinforcements  $B_4C$  and  $Al_2O_3$  is used as a reinforcement. Reinforcements are used in different proportions (2%, 3% and 4% each) to make three different samples of hybrid composites. The physical and thermal properties of A359 and reinforcements  $B_4C$  and  $Al_2O_3$  are given in Table 1.

**Table 1: Physical and Thermal Properties of  $B_4C$ , A359 Alloy and  $Al_2O_3$**

	Density ( $g/cm^3$ )	Thermal Conductivity (W/m.K)	Melting Point ( $^{\circ}C$ )	Specific Gravity ( $g/cm^3$ )
$B_4C$	2.54	37	2445	2.56
A359	2.62	154.5	600	2.72
$Al_2O_3$	3.2	98.5	2072	3.62

Electromagnetic stirring was applied in the fabrication process of the hybrid metal matrix composite [2]. For cutting purpose, the abrasive water-jet machine of model "CNC WJ2020B-1Z-D" is used. The range of machining parameters selected for the study is given in Table 2

**Table 2: Specifications of Cutting Operation**

Constraints	Selected Value
Water pressure $p$ [MPa]	300
Traverse speed $v_t$ [mm/min]	50
Workpiece thickness $h$ [mm]	20
Abrasive mass flow rate $m_a$ [g/min]	300
Stand-off distance $z$ [mm]	2
Type of abrasives	Australian garnet
Mesh size $d_f$ [MESH]	80

To analyse the machining outcomes related to surface characterization, microstructural and surface detailing has been carried out. The microstructural images are taken by NIKON Eclipse 80i optical microscope (reflected light, dark field technique) and 2D, 3D detailing of the surfaces are done by Olympus LEXT OLS 3100 laser confocal microscope.

## RESULT AND DISCUSSIONS

Three different samples of hybrid MMC ( $A359/2\%Al_2O_3/2\%B_4C$ ,  $A359/3\%Al_2O_3/3\%B_4C$ , and  $A359/4\%Al_2O_3/4\%B_4C$ ) were successfully processed by AWJ cutting process. The created surfaces are similar for all three of the tested samples. The material contains isolated irregularly shaped macro-pores with the maximum size of 1.6 mm. The water-jet is passing through the pores which creates the long, thin water channels on the machined surface. Due to which the surfaces seems to be slightly swelling type. The macro-pores are unevenly distributed in the material. This is due to the fact that during cutting process some of the hard reinforcement abrasive particles which are lying in the path of cutting were loosening up and dislodged from the cutting surfaces. It leads to the macro-pores were observed on the machined surfaces. Figure 1 (a, b, c) shows the microscopic images of the machined surface of the testing samples. At first sight all three images were seemed similar to each other. However, the size of the cutting traces and long furrows are different at microscopic view.



**Figure 1 (a): Microscopic Image of Machined Surface of Sample  $A359/2\%Al_2O_3/2\%B_4C$**

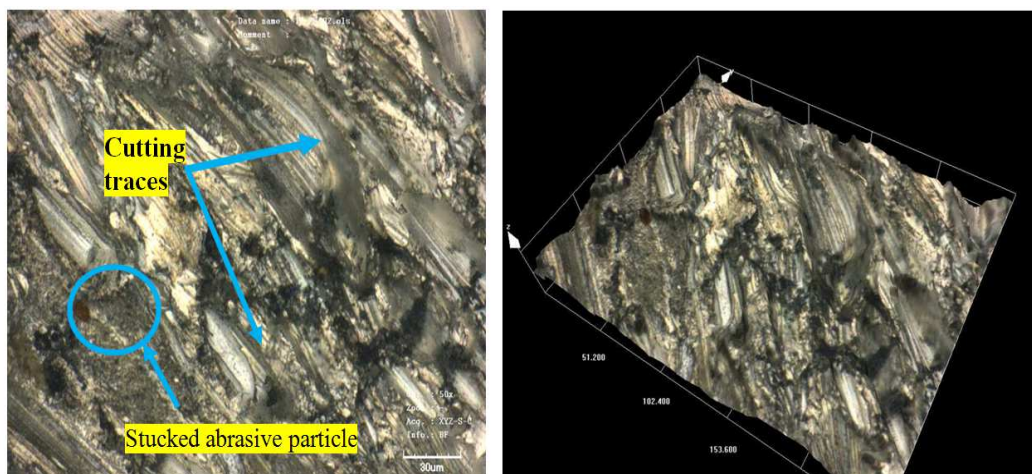


**Figure 1 (b): Microscopic Image of Machined Surface of Sample  $A359/3\%Al_2O_3/3\%B_4C$**



**Figure 1 (c): Microscopic Image of Machined Surface of Sample A359/4%Al<sub>2</sub>O<sub>3</sub>/4%B<sub>4</sub>C**

It has been observed that while increasing the percentage of reinforcement, the machined surface gets rougher in nature. This is due to the ploughing nature of cutting in AWJ processing. Some of the macro-pores were also observed as seen in figure 1 (a). An abrasive grain (reddish brown in colour, figure 1 (c)) is found stuck on the machined surface, visible on the right of the image. Figure 2 (a, b, c) shows the 2D and 3D detailing of the machined surfaces of tested hybrid MMCs taken by Olympus LEXT OLS 3100 laser confocal microscope. The common observation was observed for each tested sample such as the cutting traces are observed on each machined surface. This is due to the striking of abrasive grains on the workpiece surfaces. These cutting traces seem parallel to each other. In some cutting traces, fine grooves were also observed. Some traces are overlapped to each other and also seen in curved structures. However, at the microscopic level, more cutting traces were observed in sample with lower reinforcement (figure 2 (a)) compared to the sample of higher reinforcement (figure 2 (c)). This is due to the fact that at the lower range of reinforcement, the material is more ductile in nature. Hence sample with a lower range of reinforcement is more plastically deformed than sample with higher reinforcement. Some abrasive particles are also found stuck on the machined surface.



**Figure 2 (a): 2D and 3D Surface Detail of sample A359/2%Al<sub>2</sub>O<sub>3</sub>/2%B<sub>4</sub>C**





Figure 2 (b): 2D and 3D Surface Detail of Sample A359/3%Al<sub>2</sub>O<sub>3</sub>/4%B<sub>4</sub>C

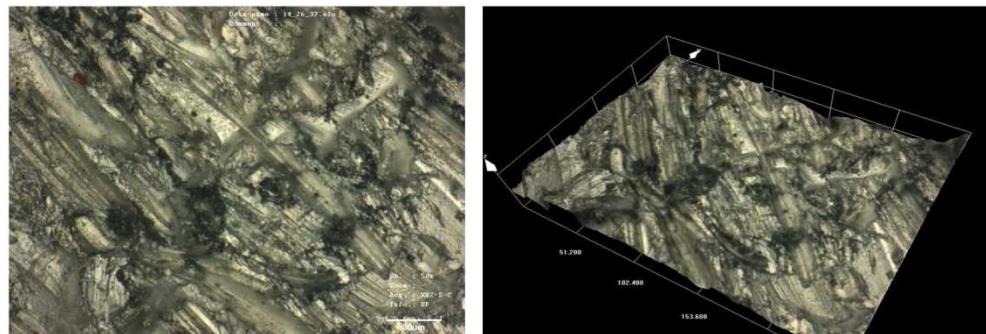


Figure 2 (c): 2D and 3D Surface Detail of Sample A359/4%Al<sub>2</sub>O<sub>3</sub>/4%B<sub>4</sub>C

## CONCLUSIONS

All three tested samples of hybrid MMCs were successfully processed by AWJ cutting. It has been observed that AWJ cutting process is one of the preferred choices of machining for hard materials such as MMCs. Some findings were observed during cutting process of hybrid MMCs are as follows:

- It has been experimentally noticed that while increasing the percentage of reinforcement, the rough machined surface is found.
- Cutting traces are observed on each machined surface. This is due to the striking of abrasive grains on the workpiece surfaces.
- Cutting traces are seeming parallel to each other. In some cutting traces, fine grooves were also observed.

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